AN OVERLAPPING GRID ALGORITHM FOR FINITE ELEMENT SOLUTION OF FLUID-STRUCTURE INTERACTION PROBLEMS

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Several physical problems, such as wind tunnels and fluidized-bed reactors, involve moving and/or deformable solid bodies which are surrounded by, and interact with, moving fluids. The numerical implementation of the necessary cross-mesh constraints presents a number of challenges. The use of Lagrangian meshes for both phases would be severely limited by mesh distortion as the fluid domain conforms to the solid motion. An alternative to this is to construct a continuous Eulerian mesh for the fluid and allow the solid mesh to overlap it, with interaction conditions imposed along the solid boundary. However, this presents a problem for programs which use sparse matrix storage formats (e.g. MSR or VBR). As the solid moves, it will overlap different regions of the fluid domain, requiring the constraints to be imposed on different fluid elements. Therefore, the unknown mapping for the Jacobian matrix would have to be updated at each time step.

Alternatively, these constraints may be imposed as augmenting conditions on the conservation equations of the individual phases. Here, a level set equation is used on the fluid side to track the solid boundary location to determine where the interactions apply. Continuity of velocity or stress is imposed by Lagrange multiplier constraints along the solid boundary. The corresponding Lagrange multiplier unknowns are then used to apply corrections to the fluid momentum and solid displacement equations, in accordance with the work of Baaijens[1]. These constraints are coupled to the main problem through a bordering algorithm applied at each Newton iteration.

Results of this algorithm demonstrate incorporation of the relevant physics without a large increase in computational expense. As a typical example, a ball falling through a column of fluid imparts a velocity profile to the fluid, which moves downward with the solid. In turn, the drag exerted by the fluid acts against the acceleration of gravity, resulting in a significantly slower fall than if no ambient fluid were present.

References

[1] F. P. T. Baaijens, "A fictitious domain/mortar element method for fluid-structure interaction," *International Journal for Numerical Methods in Fluids*, v. 35, p. 743-761, 2001.